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BATTLING WEEDS ON MINNESOTA FARMS

POISED like grim shadows o'er
Weeds lurk to blight with evil
The tiller's harvest, waste his toi
Mar his prospect, foul the soil.

Oh, you who plow and reap and sow,
Guard well your acres from this foe;
Nor vigil cease, nor labor spare,
Lest weeds become harsh tyrants there.

Agricultural Experiment Station
University of Minnesota

Summary

Weeds may be controlled by three general methods: fallow, cropping (or a combination of both), and the use of chemicals.

Quack grass may be eliminated gradually by following two- to five-year rotations, including a cultivated crop, if the necessary extra tillage is given beginning in August preceding the year the field is to be in the intertilled crop.

Field bindweed may be eradicated in two to three years by a full season of cultivation with a duckfoot cultivator followed by rye or winter wheat seeded about September 15. The grain is removed as early as possible and cultivation resumed.

An interval of two weeks between cultivations is more effective in bindweed control than more frequent tillage.

Cultivation of bindweed fields until July 1, followed by a summer competitive crop, has proved valuable. Sudan grass, millet, sorghum, and soybeans were the best crops tested.

Sodium chlorate was the most effective chemical for eradicating long-lived perennials. Its cost prohibits its use on large areas. Sodium chlorate may be applied as dry powder or as a spray. In general, applications are most effective when made in the late summer or early fall.

Under the conditions of southwestern Minnesota, an application of about 500 pounds of sodium chlorate per acre appeared most satisfactory.

A proprietary compound with a sodium salt of dinitrocresol as its principal ingredient has proved effective in killing the mustards, wild radish, wild buckwheat, and the ragweeds. It is selective in its action and may be applied to fields of flax when the plants are small with little damage to the flax.

Crabgrass, dandelions, and mouse ear chickweed were destroyed by spray applications of one-half gallon of water-white kerosene (color Saybolt 23) to each 100 square feet.

Field bindweed was eradicated in two to three seasons on areas seeded to rye or winter wheat and grazed with sheep until the middle of June, followed by summer fallow and the grain seeded again September 15.

Sheep will eat leafy spurge and may be used to destroy the plants if the grazing is intensive.

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Battling Weeds on Minnesota Farms

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LIKE INSIDIOUS diseases, weedy plants often become well established before the farmer realizes what is happening. The universal presence of undesirable species leads to an indifference on the part of many. Too often the attitude is one of defeatism; weeds are here, always have been here, and always will be. The rapid distribution of especially harmful weeds such as field bindweed (*Convolvulus arvensis*) and leafy spurge (*Euphorbia Esula*) has resulted in damage so spectacular that even the nearest-sighted individual should not fail to recognize the seriousness of the situation. Undoubtedly weed plants in Minnesota cost farmers many millions of dollars. It is almost impossible to determine the actual losses as they are so widely varied. An estimate should include not only reduction in yield and added labor but also the costs of additional transportation and cleaning, and the reduced value of processed grain.

Classification of Weedy Plants

Weeds are plants that persist in growing where they are not wanted. Sometimes a desirable crop plant may be considered a weed, such as rye growing in winter wheat. Plants which are weeds because of their general undesirability and difficulty of control will be considered here.

Weedy plants are commonly classified in three groups, depending upon their undesirability and ease of control. The groups are:

1. **Noxious**—These weeds are especially persistent or are very undesirable because of their harmfulness. For example, field bindweed is noxious because it is so persistent. Frenchweed (*Thlaspi arvense*) is noxious because of its effect upon milk and other dairy products when the plants have been eaten by the cow.

2. **Semi-harmful weeds**—These plants, such as golden rod (*Solidago* spp.), while undesirable, are not so serious as those in the noxious group.

3. **Common weeds**—These include the widely distributed plants such as the foxtails (*Setaria* spp.) and the pigweeds (*Amaranthus* spp.), plants which are easily controlled as a rule.

Weeds may be classified according to their length of life, e.g., annuals, winter annuals, biennials, and perennials. As a rule, the perennials are the most serious because they are generally more difficult to control.

The Minnesota weed law, Chapter 377, Session Laws 1925 as amended in 1927 and 1937, lists a number of weeds as being especially undesirable. These weedy plants are divided into two groups, Class I, consisting of weeds that have been determined as noxious, and Class II. This classification follows:

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CLASS I

Common Name	Botanical Name
Austrian Field Cress	*Roripa austriaca* (Crantz) Besser
Canada Thistle	*Circium arvense* (L.) Scop.
Common Barberry	*Berberis vulgaris* (L.)
Dodders	*Cuscuta* spp.
Field Bindweed (Creeping Jenny)	*Convolvulus arvensis* L.
Horse Nettle	*Solanum carolinense* L.
Leafy spurge	*Euphorbia Esula* L.
Oxeye Daisy	*Chrysanthemum Leucanthemum* L.
Perennial Peppergrass	*Lepidium Draba* L.
Perennial sow thistle	*Sonchus arvensis* L.
Quack Grass	*Agropyron repens* (L.) Beauv.
Sheep Sorrel (Field or Red)	*Rumex Acetosella* L.
Toad-flax (Butter and eggs)	*Linaria vulgaris* Hill.

CLASS II

Common Name	Botanical Name
Annual Sow Thistle	*Sonchus oleraceus* L.
Bladder Campion	*Silene latifolia* (Mill) B. and R.
Blue Lettuce	*Lactuca pulchella* (Pursh) DC.
Buckhorn (Plantain)	*Plantago lanceolata* L.
Burdock	*Arctium minus* Bernh.
California Puncture Vine	*Tribulus terrestris* L.
Cheat	*Bromus secalinus* L.
Cocklebur	*Xanthium* spp.
Common Ragweed	*Ambrosia elatior* L.
Curled (yellow or sour) Dock	*Rumex crispus* L.
Darnel	*Lolium temulentum* L.
False Flax	*Camelina sativa* (L.) Crantz
Frenchweed	*Thlaspi arvense* L.
Giant Ragweed	*Ambrosia trifida* L.
Graveyard Spurge	*Euphorbia Cyparissias* (L.) Hill.
Hare's Ear Mustard	*Conringia orientalis* (L.) Dumort.
Hedge Buckwheat	*Polygonum scandens* L.
Hoary Alyssum	*Berteroa incana* (L.) DC.
Lady's Thumb	*Polygonum persicaria* L.
Morning Glory	*Convolvulus sepium* L.
Prickly Nightshade	*Solanum rostratum* Dunal.
Purple Cockle	*Agrostemma Githago* L.
Russian Thistle	*Salsola Kali tenufolia* Meyer
Sandbur	*Cenchrus pauciflorus* Benth.
Smartweeds	*Polygonum* spp.
Spiny Sow Thistle	*Sonchus asper* (L.) Hill
Sticky Cockle	*Silene noctiflora* L.
Tumbling Mustard	*Sisymbrium altissimum* L.
Wild Barley	*Hordeum jubatum* L.
Wild Buckwheat	*Polygonum convolvulus* L.
Wild (common) Mustard	*Brassica arvensis* L.
Wild Oats	*Avena* spp.
Wild Vetch	*Vicia angustifolia* L.

While all of the weeds listed are undesirable, the law brands those in Class I as especially bad. The law permits greater tolerance in the instance of the Class II weeds.

Seed Certification

The Minnesota Crop Improvement Association has as one of its primary functions the improvement of the quality of farm seeds. Growers of pure seed of recommended varieties may have their seed certified or registered by subjecting the growing crop to a field inspection and the harvested seed to a bin inspection. No crop seed may be registered if it contains any noxious weeds listed in Class I. Registered No. 1 seed may contain not more than .01 of one per cent and Registered No. 2 not more than .05 of one per cent seeds of any one or more weed plants listed in Class II. Registered No. 1 seed is given a blue tag, symbolic of high quality, and Registered No. 2 seed is labelled with a red tag.

FIG. 1. Field bindweed thrives in corn fields.

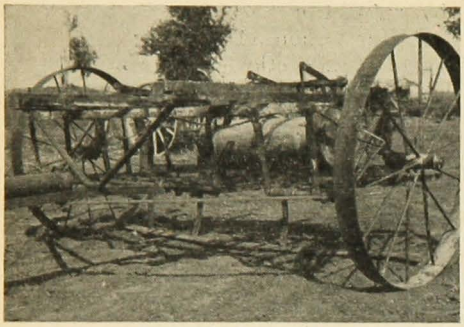

FIG. 2. (Left) Homemade blade cultivator. (Right) Duckfoot cultivator.

Controlling Weeds by Cultivation

BECAUSE of the seriousness of particular weeds, most research has been confined to relatively few species. However, the similarity of growth habits of certain species makes it possible to make general recommendations based upon studies with but a few.

Arny[2] found that the readily available and total carbohydrates reached low points in the underground storage organs of leafy spurge, Austrian field cress, perennial sow thistle, and Canada thistle about the time these weeds began flowering. From this evidence, he recommended that the cultivation of the four weeds be started at the beginning of flowering.

The average date of initiating control measures for leafy spurge and Austrian field cress was about the middle of May; for quack grass, Canada and perennial sow thistle about the first part of July. If the plants are mowed at this time, seed formation is prevented and growth is slowed appreciably.

Canada and perennial sow thistle may be eradicated effectively through growing alfalfa. The frequent cutting of the alfalfa prevents the weed plants from recovering so that eventually they are destroyed because they are unable to compete with the alfalfa. The effectiveness of the method is dependent, of course, upon the establishment of a good stand of alfalfa. In low, wet meadows where alfalfa is unsuited, reed canary grass is effective.

Quack grass recovers quickly and may be eliminated by maintaining a black fallow for at least one season. The springtooth harrow has proved valuable in this work. The operations must be repeated often enough to prevent green growth as a few days' delay may result in the recovery of the quack plants. A careless job of summer fallow usually results in a more vigorous growth of the weeds because the tillage encourages more rapid growth.

Arny[3] found that quack grass could be eradicated completely by following good two- to five-year rotations each containing a cultivated crop. Preceding the cultivated crop in the rotation, the land was carefully tilled from August until November and continued from early spring to planting time. This thorough cleanup once in each cycle of the rotation was necessary in order to eradicate the quack grass completely. Drilling corn thick for fodder

[2] Arny, A. C. Variations in the organic reserves in underground parts of five perennial weeds from late April to November. Minn. Agr. Expt. Sta. Tech. Bul. 84. 1932.

[3] Arny, A. C. Quack grass eradication. Minn. Agr. Expt. Sta. Bul. 151. 1915.

Table 1. Number of Hoeings Required to Eradicate Leafy Spurge and Perennial Sow Thistle

Weed	Year	No. hoeings per year	Total	Cost per acre*	Weeds living end: First year	Second year
					Per cent	Per cent
Leafy spurge	First	19	.....	.....	.....	.....
	Second	10	29	$1,160.00	2.0	0
Perennial sow thistle	First	14	14	560.00	25.0	0

* Computed at 25 cents per hour. On an average, a man can hoe a square rod in one hour.

and planting buckwheat about July 1 eradicated the quack grass in three years. Thorough cultivation of the fodder corn and tillage as needed to keep the land black when not in crop was mainly responsible for the eradication.

Leafy spurge and Austrian field cress may be permitted to grow for 5 to 10 days before succeeding cultivations. The effect of the growth is to deplete the reserves from the plant's roots and thus hasten its destruction.

The eradication of leafy spurge and perennial sow thistle by continuous cultivation is an expensive process. Arny, hoeing small areas, secured the results given in table 1.

While hoeing is effective, its cost is prohibitive except on small areas. Computed on an acre basis, it would cost $1,160 to eradicate leafy spurge. No farmer would attempt eradication with a hoe on large areas. The experiments emphasize the labor necessary to eliminate the worst weeds once they have gained a foothold.

In another experiment where machinery was used, cost of eradication was reduced greatly (table 2).

The use of machinery effected a great saving as compared with hand hoeings. Costs might have been reduced further by substituting disking for at least one and possibly two of the plowing opera-

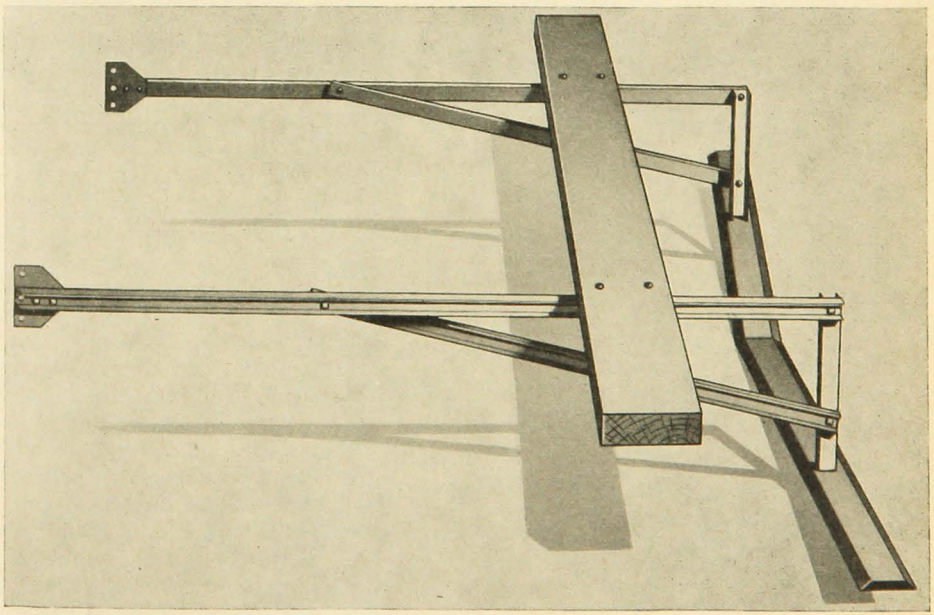

FIG. 3. Homemade tillage implement converted from two-row cultivator.

Table 2. Cost of Eradicating Leafy Spurge and Quack Grass by Machine Tillage

Weed	Year	Number of operations: Plow	Double disk	Total	Cost per acre	Weeds surviving at end: First year	Second year
						Per cent	Per cent
Leafy spurge	First	3	13	.....	.....	1.2	.....
	Second	5	10	31	$24.00	.....	0.0
Quack grass	First	2	10	12	12.10	0.0	.....

tions. These operations will be effective only if a thorough job is done. The operator cannot expect to eliminate weeds if plowing or disking are carelessly done or done only when there is nothing else to do.

The plow and the disk are found on every farm and so they were used in the experiments. A spring tooth for the quack grass and a duckfoot cultivator for the deep-rooted perennials are recommended. Not all farmers can afford to purchase special equipment for weed control. So they may find it advantageous to use their present farm equipment. Above all, considerable power is essential. Under most conditions, a tractor will furnish the power to do a good job.

At the Lamberton station, use has been made of old machinery modified to do special work. A discarded two-row cultivator was made into a satisfactory weed tool by removing the shovels and welding to them a sloping blade made from old truck springs (Fig. 3). The total cost was about $10. Any blacksmith should be able to construct these machines from either a one-row or two-row cultivator. The blade must be properly welded and kept sharp to permit the implement to cut the weeds 4 to 6 inches below the surface.

A sled type tillage machine may be made at a low cost. This device (Fig. 4) consists essentially of a sled with blades set so as to run below the soil surface. Weighting down the outfit will make it possible to do a good job at a low cost. Any blacksmith can construct the implement in a relatively short time. A machine of this type is not equal to a special weed tool such as the duckfoot cultivator and no one should expect it to do the same work. It will, however, do a satisfactory job under most conditions.

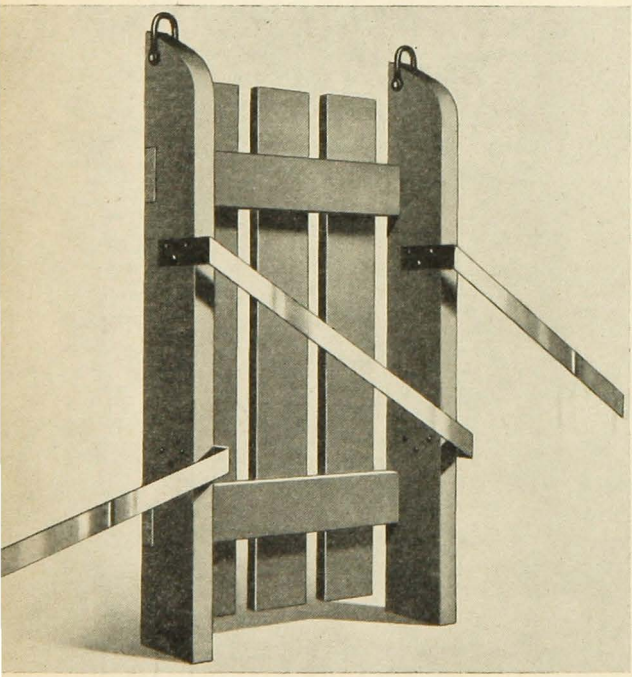

FIG. 4. Homemade sled-type tillage machine.

Controlling Bindweed by Fallow and Cropping

IN THE SPRING of 1936, the Minnesota Agricultural Experiment Station in cooperation with the Bureau of Plant Industry, United States Department of Agriculture, and the Minnesota State Department of Agriculture, initiated special investigations on the control of field bindweed (*Convolvulus arvensis*), probably the worst weed in the state. A badly infested 160-acre farm in Redwood County, 1½ miles west of Lamberton was leased for five years. Carefully planned experiments were immediately started. In general, the experimental work included three methods of attack: (1) fallow, (2) cropping plans, and (3) the use of chemicals. The use of chemicals is discussed in a later section.

FALLOW

Time of Beginning Cultivation

In the control of field bindweed or any other weed, the farmer is confronted with the problem of the best time in the year to initiate cultivation. Is it best to begin as soon as plant growth starts in the spring, or is there an advantage in delaying cultivation until growth is well established?

During each of the years 1936 to 1939, cultivation was started on a series of plots on the first of each month throughout the growing season and continued until all the bindweed plants were dead (table 3). The land was plowed to a depth of 5 inches and cultivated with a duckfoot cultivator at intervals of approximately five days after the emergence of the plants. However, in 1939 the interval between cultivations was lengthened to two weeks after emergence since other experiments showed this change to be desirable. Plots on which cultivation was started August 1 or later were cropped to oats previous to beginning the experiments.

On an average, it made little difference in the total number of cultivations required to eradicate the bindweed whether operations were started early in the season or late. From a practical viewpoint, there are several advantages of starting cultivation before midsummer. Delaying tillage after July 1 is likely to result in the development of viable seed to infest the soil and thus add to the menace of new seedlings which may develop for years afterwards.

Except for the experiments started in the very dry year of 1936, all plots receiving initial tillage in May or June were free of bindweed by July 1 of the following season, thus requiring only one and one-half crop seasons for eradication. Those plots where tillage was started later required the loss of two full crop seasons. With the elimination of bindweed by July 1 of the second year, it is possible to grow successful hay crops of sorghum, sudan grass, soybeans, or millet. This results in a return from the land, and the competition provided by the growing crops destroys any possible stray weed plants which may have escaped.

When cultivation was started as late as August, it was necessary to cultivate into the third year before bindweed elimination was complete.

The farmer who desires to begin cultivation after small grain harvest may not necessarily wait until spring of the next year to start his work. He may cultivate the rest of the season and follow up the second year with a combination of cultivation and competitive crops as discussed later in this bulletin.

Table 3. Number of Cultivations Required to Eliminate Bindweed When Cultivation Was Begun at Different Times of the Year at Lamberton, Minnesota, 1936-39

Time of first tillage	Total number of cultivations for experiments started in:				
	1936	1937	1938	1939	Average
Emergence*	25	18	17	17	19.25
June 1	26	18	16	16	19.00
July 1	29	17	18	18	20.50
August 1	27	20	17	18	20.50
September 1	26	20	17	16	21.25

* Usually about May 1-10.

Interval between Cultivations

For many years, it has been a recommended practice in controlling weeds by fallow methods to keep the soil black, that is, cultivate as often as new growth appears. With a deep-rooted perennial such as field bindweed, new growth emerges within a short time and many cultivations are required. It was reasoned that possibly the interval of cultivation could be extended to take advantage of possible depletion of root reserves in the formation of plant growth. The new growth must be made at the expense of reserves, and a series of experiments was outlined to determine when the plants ceased to rely upon their stored reserves and actually began the process of rebuilding these supplies. Obviously, if tillage were delayed to permit the rebuilding, little or no progress would be made in eradication. Accordingly, two series of plots were planned. In one series the field was plowed in the spring when the first bindweed growth started, and the other series was plowed after grain harvest about August 1. These two dates of initial plowing coincide with general farm practices. In 1936 and 1937 the plowed areas were cultivated with a duckfoot cultivator. One plot was cultivated immediately upon emergence of new growth; another 4 days after re-emergence; and other plots 8, 12, and 16 days after each re-emergence. In 1938 and 1939 other plots were cultivated 20, 24, and 28 days after re-emergence. The number of cultivations required for eradication of the bindweed are shown in tables 4 and 5.

Much labor and expense were saved by extending the interval between cultivations. In both the spring and midsummer series, an interval of 12 to 16

Table 4. Number of Cultivations Necessary to Eliminate Field Bindweed with Different Intervals between Cultivations (First Cultivation May 1), Lamberton, 1936-39

When cultivation began	Number of cultivations for experiment started in:					Average number of days between cultivations	
	1936	1937	1938	1939	Average	First year	Second year
Days after emergence							
At emergence	32	24	27	25	27.0	8	10
4	25	21	22	22	22.5	11	12
8	17	17	18	19	17.7	15	18
12	15	14	16	17	15.5	19	22
16	13	14	15	16	14.5	22	24
20	.....	.....	12	13	12.5*	26	30
24	.....	.....	15	10	12.5*	30	34
28	.....	.....	15	9	12.0*	34	40

* Two years only.

Table 5. Number of Cultivations Necessary to Eliminate Field Bindweed with Different Intervals between Cultivations (Initial Cultivation August 1), Lamberton, 1936-39

When cultivation began	Number of cultivations for experiment started in:					Average number of days between cultivations	
	1936	1937	1938	1939	Average	First year	Second year
Days after emergence							
At emergence	32	28	30	21	27.5	12	10
4	23	24	26	19	23.0	16	13
8	19	19	22	17	19.2	20	16
12	18	16	20	14	17.0	22	19
16	15	15	20	11	15.2	26	22
20	.....	.....	17	11	14.0*	30	27
24	.....	.....	17	11	14.0*	32	35
28	.....	.....	17	7	12.0*	35	38

* Two years only.

days resulted in the destruction of the weeds by the fewest cultivations. On an average, delaying cultivation until 16 days after emergence reduced the required number of tillage operations as well as labor costs almost one half.

While two-year results indicate that the interval might be extended beyond 16 days, this is not practical. The chief disadvantage is that the soil becomes very hard and it is extremely difficult to operate the duckfoot cultivator. Also, it is advisable to provide for a margin to protect against unavoidable delays in cultivating. For these reasons, it seems advisable to cultivate every **14 days.**

It was more difficult to destroy the bindweed when cultivation was started in late summer than when begun early in the season. Most farmers will find it advisable to start work in June. This confirms the results in table 3.

Cost of Eradicating Bindweed by Fallow

Careful cost account records at the Lamberton station indicate that doing a good job of tillage spread over two years will cost about $12.70 per acre. Cultivation must be thorough for good results. This entails fairly deep plowing (5 inches) and cultivating with the duckfoot at a 5-inch depth. The average costs per acre per cultivation as determined from 1936 to 1941 were as follows:

	per acre
Average cost for gas, oil, and labor	**$0.38**
Depreciation and repairs	**0.08**
Total cost	**$0.46**

On the average farm the costs probably will run higher, and under present conditions it appears that 50 cents per acre represents a fair charge for each cultivation with a duckfoot. Based on a cost of 50 cents per acre, the following expenses are representative:

	per acre
Plowing once each season	
Two plowings at $1.35	**$2.70**
10 cultivations per season	
Twenty cultivations at .50	**10.00**
Total	**$12.70**

To these costs it is necessary to add the acre rental cost, thus increasing the cost appreciably. The cost of fallow is a heavy tax on the land. The actual cost of operation where the labor, gasoline, and oil only are considered may run as low as 20 to 25 cents per acre. This does not represent the true situation because depreciation is a major item of expense. **The use of crops in combination with tillage should prove helpful in reducing eradication costs.**

CROPPING PRACTICES

Competitive Crops

Nearly every farmer prefers to control or eliminate undesirable plants by cropping practices. One of the fundamentals of a good crop rotation is to grow a cultivated crop and thus control weeds. In the early agricultural history of Minnesota, little thought was given to proper rotations. As a result, weedy plants became a very serious problem. Many of the weed problems confronting us today are the result of this period when little attention was given to cultivated crops and weed control.

While some weeds are controlled entirely by the growing of certain crops, it is necessary in most cases to supplement the crops with tillage to destroy such weeds as field bindweed. The successful growing of economic crops results in a return from the land and should, if effective, materially reduce the costs of eradication. Many farmers possessing farms infested with noxious weeds have been unable to cope with the situation because they could not afford to use chemicals to eliminate the weeds or to sacrifice the crops to permit a system of fallow. It was to meet such situations and to learn of more economical and practical methods of bindweed control that the cropping experiments were initiated.

One likes to think of crops competing with weeds as well as weeds competing with crops. The success with which certain plants compete with desirable plants is largely the reason why the undesirables are classed as weeds. For investigation, the crops which appeared promising as competitors were divided into two groups, based upon the time of planting.

Fall competitive crops—In much of the bindweed area of Minnesota, rye or winter wheat is common. Since in southwestern Minnesota the climate is not suitable for winter wheat, rye is much more reliable. Experiments at Lamberton included the use of rye and winter wheat seeded September 1 and 15, both with a preceding period of a

FIG. 5. Soybeans planted after early summer tillage.

full season cultivation. On one series of plots, an oat crop was produced previous to plowing. This permitted tillage for only a part of the season. The alfalfa plots were included for comparison.

In 1938 and 1939, both rye and winter wheat yielded well. Satisfactory yields were due in a large measure to the effect of the fallow methods and special care in seedbed preparation. Yields are given as averages for two years as this enables one to consider them in relation to the total cost of eradication.

Delaying seeding for about two weeks was important in furthering weed control. The delay permitted at least one more cultivation and this last cultivation was especially effective. While all plots showed almost complete bindweed elimination at the end of three years, the plots seeded to rye on September 15 gave complete eradication by July of the second year.

Growing rye as compared with the continuous cultivation or fallow method (tables 4 and 5) reduced the number of cultivations required to eradicate the weeds and made possible a cash crop in two of the three years included in the trials. The returns made possible by growing crops while eliminating the weeds are essential to most farmers if they are to remain in business. When rye was used, the eradication was almost as rapid, as measured in total elapsed time, as when continuous fallow was practiced.

Winter wheat reduced the stands of bindweed greatly, but under the conditions at Lamberton, the stands of wheat were spotted as a result of winter injury, and the competitive effect was less complete than where rye was used.

The alfalfa was planted alone at a rate of 12 pounds per acre on land that had been cultivated with a duckfoot six times. The six cultivations in 1937 represent all of the tillage operations during the three years. An average acre yield of more than 3 tons of hay was secured each year. At the end of the period, the bindweed stand was reduced greatly. The remaining plants were very weak, indicating that they had suffered from the competition with the alfalfa.

In the three years' trials, no seed was produced by any of the bindweed plants. While it does not appear that enough evidence is available to prove that alfalfa will eliminate bindweed, the results show that a farmer may grow alfalfa on a part of his infested farm while he is carrying out eradication of other fields. Precautions should be taken against the spread of the weeds through transport of hay and use of the manure on clean areas as there

Table 6. Yield of Fall Competitive Crops, Number of Cultivations, and Survival of Bindweed after Treatment, Lamberton, 1937-40

Treatment each year, 1937-39*		Average 2-year crop yields per acre	Total No. of cultivations, 1937-39	Number of bindweed plants per square yard in July		
Cultivation from harvest to:*	Crop seeded after cultivation			1938	1939	1940
		bu.				
September 1	Rye	27.8	13	1	T†	T
September 15	Rye	34.1	17	1	0	0
September 1	Wheat	16.6	13	1	1	0.2
September 15	Wheat	19.3	17	0.5	T	T
September 20	Rye	34.1	3	11	9	4.3
August 1‡	Alfalfa for hay	3.16 tons	6	8	2	0.3

* In 1937, the land was left idle and cultivated up to the dates indicated with exception of the September 20 date on which plot oats were plowed and cultivation begun.

† T = trace, less than 100 plants per acre.

‡ No cultivation after 1937.

is some danger of bindweed seeds being produced under favorable conditions. The possibility of producing good alfalfa crops under conditions of severe infestation should aid most farmers in carrying out a clean-up program. The vigor of the bindweed plants was greatly reduced by the competition with alfalfa for light and moisture and probably by the repeated cuttings.

It is imperative that a good stand of alfalfa be secured. This is possible by thorough tillage until time to plant and the use of a cultipacker to firm the soil, insuring a firm seedbed so essential to quick growth of alfalfa. Without these precautions, the alfalfa stand may be poor and ultimate failure may result.

Summer competitive crops—A summer competitive crop is one planted in the late spring or early summer, late enough to permit effective cultivation previous to seeding and early enough to insure the successful development of a crop. Based upon conditions at Lamberton, the usual plan was to cultivate the land until July 1 and then seed the competitive crop. The period of cultivation retarded the growth of the bindweed until the seed of the competitive crop could germinate and become established so as to give real competition for the use of light, water, and soil nutrients. An implement such as a cultipacker was essential to firm the loose soil and thus hasten germination and rapid early growth. A relatively short delay in emergence may result in failure of the competing crop to gain an advantage over the weeds.

Sorghum, sudan grass, millet, field corn drilled in close rows, soybeans, sunflowers, buckwheat, hemp, and oats were tested. The production of the crops and their effectiveness in furthering the elimination of bindweed are illustrated in table 7.

Many farmers grow oats on bindweed infested land. As shown in table 7, the oat crop does not compete successfully with bindweed. It was included here for comparison. While fair crops of spring-seeded small grain can be produced on bindweed infested land which

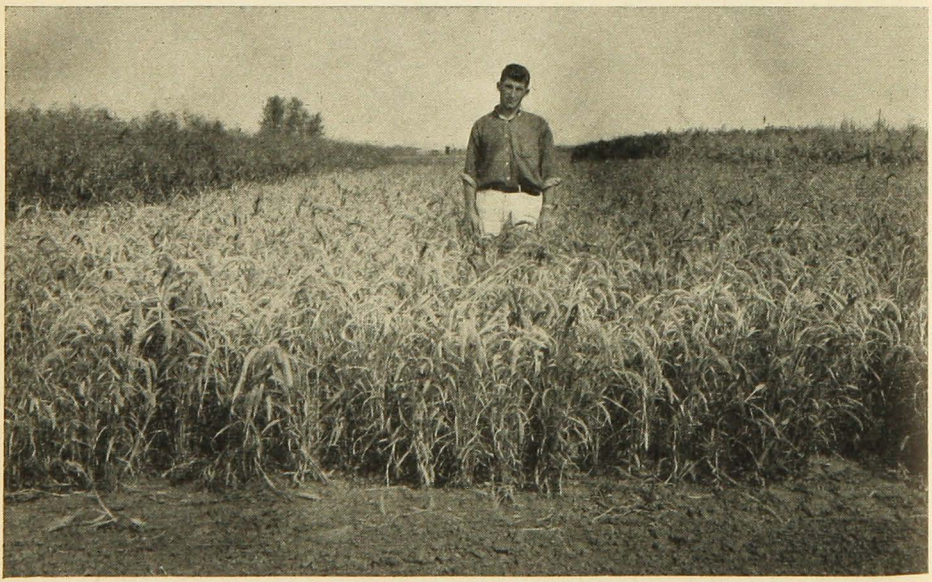

FIG. 6. Millet seeded July 1 produces much hay and checks bindweed.

FIG. 7. Sudan grass grows rapidly when seeded in midsummer.

had been carefully prepared, in years of moisture shortage the grain crop is certain to yield poorly. Also the bindweed plants make it difficult to harvest the crop and to cure it rapidly in the shock. The green foliage of the bindweed makes it next to impossible to use a combine to advantage.

Soybeans, foxtail millet, sweet sorghum, or sudan grass may be used effectively in competition with bindweed. Where a farmer can use the forage produced, he may find one or more of these crops suitable. The total required cultivations were about the same as where winter wheat and winter rye were used.

Table 7. Yield in Tons Per Acre of Summer Competitive Crops, Number of Cultivations, and Survival of Bindweed after Treatment, Lamberton, 1937-40

Treatment each year, 1937-39 Cultivate to July 1 Then seed:	Average crop yield 3 years	Total No. of cultivations, 1937-39	Number of bindweed plants per square yard in July		
			1938	1939	1940
	Tons				
Soybeans	1.7	14	2.5	2	T‡
Millet	1.4	14	5.4	6	T
Sorghum	3.2	14	6.0	5	T
Sudan	2.2	14	3	3	T
Corn	2.4	14	5	4	2
Sunflowers	*	14	4.5	5	2
Hemp	*	14	4.5	9	3
Oats for grain as check plot	33.3 bu.	3†	18	21	19

* No yield taken.

† Land plowed each year, disked, harrowed, and seeded.

‡ T = trace, less than 100 plants per acre.

FIG. 8. Sheep pastured on rye to eradicate bindweed.

While occasional plants persisted after each of the four crops, they were weak and could be eliminated in one more season.

Sunflowers, hemp, and buckwheat, in combination with early season fallow, proved ineffective in eradicating the bindweed.

Sheep on Bindweed Land

At the Lamberton station, sheep were grazed on areas seeded to winter wheat and rye. Following the end of the pasture period, the plots were cultivated until time for an early reseeding. This method has proved successful as the sheep relish the bindweed plants, frequently choosing them in preference to the rye or wheat plants. Two to three years of this plan have resulted in complete eradication of the bindweed.

Bindweed stands were greatly reduced in a bluegrass pasture where overgrazing was avoided and the pasture was given a liberal coating of barnyard manure. While bluegrass pasture cannot be used to eliminate the bindweed, it should be possible to provide good pasture in spite of the infestation and thus serve as a stop gap until eradication methods can be used.

Chemicals in Weed Control

TO MOST PEOPLE, chemicals for weed control are alluring. They like to think of the chemical eradicant as a selective agent, one that will destroy the undesirable and leave the desirable plants. This is possible with some annual weeds, but in general it is only a hope.

Chemical eradicants do have a place in a weed control program and many have been developed for this purpose. Relatively few chemicals are economical enough to permit their use on any sizeable area of land or on any but the most valuable soil. Every known chemical offering weed control possibilities has been tested at Lamberton. A few of the more important types will be discussed.

Carbon bisulfide, an effective chemical in some sections, has proved of doubtful value in Minnesota. The original cost is prohibitive, and it is difficult to apply to the soil. The gas it releases is very explosive so that its storage and handling is exceedingly hazardous. Under favorable soil moisture and temperature conditions, complete kills were obtained but at costs too great to make its use practical.

Ordinary salt, sodium chloride, is an effective weed eradicant. Its cost is prohibitive when applied in quantities sufficient to destroy weeds. Furthermore, if salt is applied at a heavy rate, it sterilizes the soil preventing growth of desirable plants for many years.

A proprietary compound which is reported to have sodium chlorate and calcium chlorate as its active ingredients has been tested in Minnesota, and the results have not warranted its recommendation to farmers.

Sodium chlorate has been found after long and extensive testing to be the most efficient weed control chemical available to Minnesota farmers. This chemical resembles common salt and is rather closely related to it in composition. In fact, livestock will eat sodium chlorate if given an opportunity. Since it is poisonous, avoid using sodium chlorate in areas available to livestock.

Prior to the initiation of work at the Lamberton weed farm, Arny made intensive trials with chemicals on several weeds. The work on field bindweed was done on a farm in Watonwan County, near Mountain Lake. On another farm directly across the road, in Cottonwood County, similar trials were carried out on leafy spurge. The fact that the work on these two weeds was carried out on adjacent farms makes direct comparisons of the efficiency of sodium chlorate in their eradication possible. The work on Austrian field cress was carried out on a farm in Olmsted County near Rochester, and that on quack grass was done the same year on a farm in Ramsey County near the University Farm.

The suitability of sodium chlorate as an eradicant is so well established that it is not considered necessary to present data on its effectiveness in comparison with other chemicals. Because it is expensive to use on large areas, such problems as rate and time of application loom as important considerations.

BINDWEED

Initial applications at rates ranging from 0.50 pounds to 4.0 pounds per square rod were made March 30, May 15, June 14, and August 16 on the farm in Watonwan County. On November 6, applications ranged from 1.0 to 4.0 pounds per square rod. The initial applications were followed by retreatments throughout the season, as indicated in table 8. The chemical was applied both as a dry salt and in solution as a spray.

Table 8. Comparative Effectiveness in Killing Field Bindweed of Uniform Initial Applications of Sodium Chlorate in Pounds Per Square Rod, in Solution or Dry, at Intervals from May to November, and Retreatments, Making the Total Applications Indicated, Watonwan County, 1929

First application, pounds per square rod	Retreatments on			Total application	Per cent full stand June, 1930	Retreatments on		Total application	Per cent full stand June, 1930
	7-18	8-16	10-16			8-16	10-16		
	Pounds	Pounds	Pounds	Pounds		Pounds	Pounds	Pounds	
	First application May 15					First application July 18			
4 sol.*	1.00	1.00	1.00	7.00	0	.....	1.00	5.00	0
4 dry	1.00	1.00	1.00	7.00	0	.....	1.00	5.00	0
3 sol.	1.00	1.00	1.00	6.00	0	.....	1.00	4.00	0
3 dry	1.00	1.00	1.00	6.00	0	.....	1.00	4.00	0
2 sol.	1.00	1.00	1.00	5.00	0	.....	1.00	3.00	0
2 dry	1.00	1.00	1.00	5.00	0	.....	1.00	3.00	0
1.5 sol.	1.00	1.00	1.00	4.50	0	.....	1.50	3.00	0
1.5 dry	1.00	1.00	1.00	4.50	0	.....	1.50	3.00	0
1.0 sol.	1.00	1.00	1.00	4.00	0	1.00	1.00	3.00	0
1.0 dry	1.00	1.00	1.00	4.00	0	1.00	1.00	3.00	0
.75 sol.	.75	.75	.75	3.00	15	.75	.75	2.25	0
.75 dry	.75	.75	.75	3.00	13	.75	.75	2.25	6
.50 sol.	.50	.50	.50	2.00	10	.50	.50	1.50	20
.50 dry	.50	.50	.50	2.00	17	.50	.50	1.50	23
	First application June 14					First application August 16			
4 sol.	1.00	1.00	1.00	7.00	0	.....	.....	4.00	0
4 dry	1.00	1.00	1.00	7.00	0	.....	.....	4.00	0
3 sol.	1.00	1.00	1.00	6.00	0	.....	.....	3.00	0
3 dry	1.00	1.00	1.00	6.00	0	.....	.....	3.00	0
2 sol.	1.00	1.00	1.00	5.00	0	.....	1.00	3.00	0
2 dry	1.00	1.00	1.00	5.00	0	.....	1.00	3.00	0
1.5 sol.	1.00	1.00	1.50	5.00	0	.....	1.50	3.00	0
1.5 dry	1.00	1.00	1.50	5.00	0	.....	1.50	3.00	0
1.0 sol.	1.00	1.00	1.00	4.00	0	.....	1.00	2.00	8
1.0 dry	1.00	1.00	1.00	4.00	0	.....	1.00	2.00	14
.75 sol.	.75	.75	.75	3.00	10	.....	.75	1.50	20
.75 dry	.75	.75	.75	3.00	8	.....	.75	1.50	28
.50 sol.	.50	.50	.50	2.00	12	.....	.50	1.00	30
.50 dry	.50	.50	.50	2.00	15	.....	.50	1.00	35
	First application November 6								
4 sol.	.....	.....	.....	4.00	20				
4 dry	.....	.....	.....	4.00	23				
3 sol.	.....	.....	.....	3.00	50				
3 dry	.....	.....	.....	3.00	65				
2 sol.	.....	.....	.....	2.00	50				
2 dry	.....	.....	.....	2.00	50				

* Sol. = solution.

Considering the amount of chlorate necessary to eradicate the field bindweed, late summer applications were most effective. A single application of 3.0 pounds per square rod on August 16 resulted in complete destruction of the bindweed. Complete eradication was secured with a total treatment of 2.25 pounds when the plots were given an initial application of 0.75 pounds on July 18, followed by equal amounts August 16 and October 16. These later light applications were more effective than similar amounts applied earlier in the season.

The early season treatments were effective if followed by several applications later in the season. Considering the added cost of retreatment, a single treatment late in the summer or in the early fall is preferable.

The late applications in November

reduced the stand but failed to eradicate the weeds. Under the conditions of the experiments, the November date was too late for effective treatment.

The results show little or no differences between dry and spray applications so the method used is primarily one of convenience to the operator.

Chemical Trials at Lamberton

Rate of applying chlorate—A series of plots was treated on September 1 with chlorate applied at rates ranging from 200 to 800 pounds per acre. The results are presented in table 9.

Dry or spray applications of sodium chlorate are equally effective. The use of the dry salt largely removes the fire hazard occasioned by clothing becoming saturated with the spray. The use of the dry chemical does not require the purchase of a sprayer because on small areas it may be sprinkled by hand. The use of a spreader will save considerable chlorate as it will permit applications at the proper rate. Satisfactory spreaders may be purchased or one may be made by any competent blacksmith.

Only the 800-pound per acre rate was 100 per cent effective in all years (table 9). However, the 500-pound rate was nearly as effective. With the dry application, 500 pounds per acre gave a complete kill in three of the four years included in the experiment. Applications above the rate of 600 pounds per acre have proved harmful because the heavy concentration of chlorate frequently deflocculates the soil and may render it sterile for many years. A 600-pound rate is the same as applying 3¾ pounds per square rod, a satisfactory rate under most conditions. The occasional plant which may escape destruction may be spot treated a year or two later. This is a desirable practice whenever chemicals are used as there always is a chance for plants to escape injury. Without this follow-up the work may be nullified.

Time of Applying Chlorate—Trials in which sodium chlorate was applied dry, at the rate of 400 pounds per acre (2½ pounds per square rod), on duplicate, 2-square rod plots, the first day of each month during the growing season, May to October, and on September 15 and October 15, have demonstrated quite clearly the inefficiency of spring chlorate applications.

Applications of chlorate in May or June were uniformly ineffective, May 1 applications reducing bindweed stands on an average of only about 63 per cent and June 1 applications about 67 per cent. Applications made July 1 to October 15 resulted in an average reduction in bindweed population of 90 per cent

Table 9. Survival of Bindweed Treated with Sodium Chlorate Applied at Indicated Rates Per Acre, Lamberton, 1936-39

Rate per acre	Average number of plants surviving on July 15 of following year									
	Applied as dry salt					Applied as spray				
	1936	1937	1938	1939	Average	1936	1937	1938	1939	Average
pounds	Number in square yard									
200	5.0	7.0	4.5	1.0	4.4	4.5	5.0	7.0	2.0	4.6
300	2.5	5.5	1.5	0.1	2.4	1.2	5.0	4.5	2.0	3.3
400	2.6	2.5	0.5	0.0	1.2	2.0	0.1	2.0	1.5	1.4
500	0.0	0.5	0.0	0.0	0.1	0.1	0.5	0.5	0.5	0.4
600	0.1	1.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	T*
700	0.0	0.5	0.0	0.0	0.1	0.3	0.5	0.0	0.0	0.2
800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Untreated check	.....	17.0	19.0	16.0	17.0	.....	17.0	19.0	16.0	17.0

* T = trace.

Table 10. The Effect of Time of Application of Sodium Chlorate on the Survival of Bindweed Plants, Lamberton, 1936-39*

Date of application	1936			1937			1938			1939			Average 1936-39		
	Rainfall*	Soil moisture*	Bindweed plants per square yard 1 year later	Rainfall	Soil moisture	Bindweed plants per square yard 1 year later	Rainfall	Soil moisture	Bindweed plants per square yard 1 year later	Rainfall	Soil moisture	Bindweed plants per square yard 1 year later	Rainfall	Soil moisture	Bindweed plants per square yard 1 year later
	inches	per cent		inches	per cent		inches	per cent		inches	per cent		inches	per cent	
May 1	.....	.....	7.0	4.07	25.1	10.0	7.55	18.6	5.0	2.15	23.0	8.0	4.6	22.3	6.2
June 1	2.49	14.8	9.0	4.65	24.5	9.0	3.46	21.2	3.0	3.73	17.0	11.5	3.6	19.5	5.6
July 1	.33	11.8	3.5	0.65	18.6	2.0	2.70	16.6	1.6	4.55	17.0	0.0	2.1	16.0	1.8
August 1	5.64	8.9	2.0	4.14	13.6	2.0	3.04	15.8	1.6	3.43	15.0	0.0	4.1	13.2	1.4
September 1	2.92	11.9	3.5	2.92	16.1	1.0	2.69	12.9	0.0	0.19	12.0	0.0	2.3	13.2	1.1
September 15	1.80	12.3	6.7	0.86	15.7	1.0	0.37	13.5	T†	0.61	11.0	0.0	0.9	13.1	1.9
October 1	0.02	13.6	1.0	0.02	13.1	1.5	0.21	12.6	0.0	0.61	11.0	0.0	0.2	12.6	0.6
October 15	0.00	.....	4.6	0.00	12.3	0.5	0.80	11.8	0.0	0.00	11.0	0.0	0.2	11.7	1.3
Check	.....	.....	17.7	.....	.....	16.0	.....	.....	18.0	.....	.....	18.0	.....	.....	17.0

* The average soil moisture to a depth of 4 feet at the time of chlorate application and the total amount of precipitation for a 30-day period following application are indicated because these factors may be important in determining the efficiency of chlorate as a weed eradicant.

† T = trace.

or more. There is little advantage for any one date of application between July 1 and October 15 (table 10). If only the data for 1937, 1938, and 1939 are considered, a distinct advantage is indicated for chlorate applications during September and October. The data from the 1936 experiment upset this viewpoint, however.

It should be remembered that the rates of chlorate application, 400 pounds per acre, are lower than the recommended rate for the Lamberton area.

During the four-year period, less than one inch of precipitation was recorded, as an average, for 30-day periods following applications of chlorate on September 15, October 1, or October 15, and bindweed survival for all of these dates of application is low. On an average, the September 1 and August 1 applications show equal reduction in bindweed stands. The average rainfall over the 30-day period was 2.32 inches for September, and slightly over 4 inches for August. A careful check of single application data gives no further indication of a definite association between the effectiveness of chlorate applications and precipitation recorded shortly after the date of application.

The results indicate a possible relationship between soil moisture at time of chlorate application and the effectiveness of that application in reducing bindweed stands. The moisture in the upper 4 feet of soil drops rapidly during May, June, and July from an average of 22.3 per cent on May 1 to 13.2 per cent on August 1. The decrease then continues at a much lower rate, reaching an average of 11.7 per cent by October 15. If only the data from experiments started in 1937, 1938, and 1939 are considered, this duplication of trends is almost perfect.

From a practical viewpoint, the use of chlorate probably is not justified on areas of more than one acre. If the infestation is large, it will be better to resort to cultivation or cultivation and cropping. In inaccessible places, chemicals are decidedly advantageous. The spray method is better than the application of dry chlorate by hand on steep slopes or rocky land.

Farmers already possessing a spray outfit may continue to use it, being especially careful to avoid fires from saturated clothing. **Sodium chlorate is a dangerous chemical and must be handled as carefully as gunpowder.**

LEAFY SPURGE

Leafy spurge (*Euphorbia Esula*) is a very undesirable weed plant that is primarily troublesome on poorer soils or

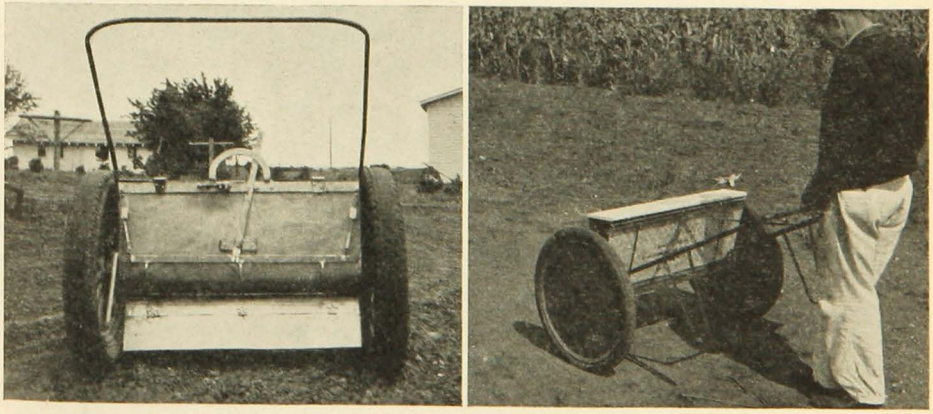

FIG. 9. (Left) Homemade chlorate spreader. (Right) Manufactured spreader.

in areas not under intensive cultivation. On fertile soils where the rotation includes a cultivated crop, leafy spurge should be controlled with good farm practices. This involves the use of a good rotation, including a cultivated crop such as corn.

In areas where it is impossible to follow cropping practices, leafy spurge has been controlled by intensive grazing with sheep. Here it appears desirable to confine the sheep to relatively small areas so that the animals will eat the plants back closely. If desirable grasses or legumes are available, the sheep may eat these in preference to the spurge.

Extensive trials in the control of leafy spurge with sodium chlorate were made on a farm in Cottonwood County (table 11).

Applications of chlorate were initiated March 30, May 15, June 14, August 16, and November 6. In every case except the November treatment, follow-up treatments were made at different rates. The results show that the most effective treatments were those initiated in June when 4 pounds of sodium chlorate per square rod were applied, followed by 1 pound August 15 and 1 pound October 15, for a total application of 6 pounds per square rod. These treatments showed nearly complete destruction of the leafy spurge plants when counts were made in June of the following year.

Plots receiving their first application of 4 pounds August 16, followed by 1 pound October 15 for a total of 5 pounds per square rod, gave nearly as good results, as less than 1 per cent of stems remained in November of the following year.

One application of 4 pounds in the fall failed to destroy all spurge plants, but it did reduce the stand very materially. Considering the cost of retreatment and the fact that less chlorate was used indicates that the late summer or fall treatments may be recommended. It appears desirable to make an application of 4 pounds per square rod in the late summer and follow this with a second treatment of 1 to 2 pounds the following year. The retreatment should be made only directly on the areas where growth has not been destroyed.

Dry or spray applications of chlorate showed little difference. In some cases, one method was superior; in other cases, the reverse held.

With the new types of chlorate that may be spread easily, the dry powder is satisfactory. On the other hand, those who possess spray equipment may find it somewhat easier to regulate rates of application in places not readily accessible through the use of chlorate in solution. The method used is primarily one of convenience.

Where tillage is possible, it is more economical to eliminate leafy spurge through cultivation than chemicals. On small areas chlorate may be used to clean up the infestation as quickly as possible. Where the infestation is more general, the land may be plowed deep late in the fall and cultivated throughout the following season. This period of tillage may be followed by rye or winter wheat as is recommended for the control of field bindweed.

QUACK GRASS

Quack grass (*Agropyron repens*) is a troublesome weed throughout Minnesota. Where clean tillage can be followed, the weed is rather easily controlled. However, it may become established in meadow areas and become a real problem. Many alfalfa fields are so badly overrun with quack grass that they are of little value.

Where the quack has gained a firm foothold, a season of black fallow is usually effective. Cultivation as often as the plants appear is essential to eliminate the weeds. If the growth is permitted to progress until the field is green, the plants will store food, and

Table 11. Comparative Effectiveness in Killing Leafy Spurge of Uniform Applications of Sodium Chlorate in Pounds Per Square Rod, in Solution or Dry, at Intervals from March to November, and Retreatments, Making the Total Application Per Square Rod Area as Indicated, Cottonwood County, 1929

First application, pounds per square rod	Retreatments on			Total application	Per cent full stand June, 1930	Retreatments on			Total application	Per cent full stand June, 1930
	7-17	8-15	10-15			7-17	8-15	10-15		
	Pounds	Pounds	Pounds	Pounds		Pounds	Pounds	Pounds	Pounds	
	First application March 30					First application June 14				
4 sol.	1.00	1.00	1.00	7.00	0.8	.....	1.00	1.00	6.0	1.0
4 dry	1.00	1.00	1.00	7.00	4.0	.....	1.00	1.00	6.0	3.0
3 sol.	1.00	1.00	1.50	6.50	8.0	.....	1.00	1.50	5.5	1.0
3 dry	1.00	1.00	1.50	6.50	12.0	.....	1.00	1.50	5.5	5.0
2 sol.	1.00	1.00	1.50	5.50	6.0	1.00	1.00	1.50	4.5	3.0
2 dry	1.00	1.00	1.50	5.50	12.0	1.00	1.00	1.50	4.5	3.0
1.5 sol.	1.00	1.00	1.50	5.00	8.0	1.00	1.00	1.50	4.0	3.0
1.5 dry	1.00	1.00	1.50	5.00	12.0	1.00	1.00	1.50	4.0	8.0
1.0 sol.	1.00	1.00	1.00	5.00*	10.0	1.00	1.00	1.00	4.0	13.0
1.0 dry	1.00	1.00	1.00	5.00*	18.0	1.00	1.00	1.00	4.0	6.0
.75 sol.	.75	.75	.75	3.75†	47.0	.75	.75	.75	3.0	15.0
.75 dry	.75	.75	.75	3.75†	43.0	.75	.75	.75	3.0	28.0
.50 sol.	.50	.50	.50	2.50‡	50.0	.50	.50	.50	1.5	57.0
.50 dry	.50	.50	.50	2.50‡	55.0	.50	.50	.50	1.5	58.0
	First application May 15					First application August 16				
4 sol.	1.00	1.00	1.00	7.00	5.0	.....	.....	1.00	5.0	1.6
4 dry	1.00	1.00	1.00	7.00	8.0	.....	.....	1.00	5.0	2.5
3 sol.	1.00	1.00	1.50	6.50	5.0	.....	.....	1.00	4.0	1.6
3 dry	1.00	1.00	1.50	6.50	8.0	.....	.....	1.00	4.0	3.0
2 sol.	1.00	1.00	1.50	5.50	8.0	.....	.....	1.50	3.5	2.0
2 dry	1.00	1.00	1.50	5.50	12.0	.....	.....	1.50	3.5	6.0
1.5 sol.	1.00	1.00	1.50	5.00	8.0	.....	.....	1.50	3.0	5.0
1.5 dry	1.00	1.00	1.50	5.00	12.0	.....	.....	1.50	3.0	8.0
1.0 sol.	1.00	1.00	1.00	5.00*	12.0	.....	.....	1.00	2.0	6.0
1.0 dry	1.00	1.00	1.00	5.00*	12.0	.....	.....	1.00	2.0	18.0
.75 sol.	.75	.75	.75	3.75†	13.0	.....	.....	.75	1.5	15.0
.75 dry	.75	.75	.75	3.75†	27.0	.....	.....	.75	1.5	20.0
.50 sol.	.50	.50	.50	2.50‡	25.0	.....	.....	.50	1.0	57.0
.50 dry	.50	.50	.50	2.50‡	60.0	.....	.....	.50	1.0	58.0
	Single application November 6									
4 sol.	.....	.....	.....	4.00	2.6					
4 dry	.....	.....	.....	4.00	3.6					
3 sol.	.....	.....	.....	3.00	5.0					
3 dry	.....	.....	.....	3.00	5.0					
2 sol.	.....	.....	.....	2.00	6.0					
2 dry	.....	.....	.....	2.00	6.0					

* Includes 1.00 application, June 14.
† Includes .75 application, June 14.
‡ Includes .50 application, June 14.

the cultivation will have little effect except possibly to stimulate better growth of the quack grass.

Where areas of infestation are small, sodium chlorate may be used to advantage.

From 4.0 to 5.0 pounds of sodium chlorate per square rod were required to eliminate all plants. A single application of as little as 2.0 pounds per square rod applied November 9 reduced the stand greatly. In June of the following year, only a few plants survived. On the basis of effectiveness and cost, the late fall application appeared most desirable.

Table 12. Comparative Effectiveness in Killing Quack Grass of Uniform Initial Applications of Sodium Chlorate in Pounds Per Square Rod, in Solution or Dry, at Intervals from May to November, and Retreatments, Making the Total Applications Indicated, Ramsey County, 1929

First application, pounds per square rod	Retreatments on				Total application	Per cent full stand June, 1930	Retreatments on		Total application	Per cent full stand June, 1930
	5-25	7-10	8-9	10-3			8-9	10-3		
	Pounds	Pounds	Pounds	Pounds	Pounds		Pounds	Pounds	Pounds	
			First application April 6					First application July 10		
4 sol.	.....	0.50	.....	0.50	5.0	0	.....	1.00	5.00	0
4 dry	.....	.50	.....	.50	5.0	0	.....	1.00	5.00	0
3 sol.	.....	.50	.....	.75	4.25	0	.....	1.50	4.50	0
3 dry	.....	.50	.....	.75	4.25	0	.....	1.50	4.50	T*
2 sol.	.....	1.00	0.75	.75	4.50	0	.....	1.00	3.00	T*
2 dry	.....	1.00	.75	.75	4.50	0	.....	1.00	3.00	T*
1.5 sol.	.....	1.00	1.00	.75	4.25	T*	1.00	.75	3.25	T*
1.5 dry	.....	1.00	1.00	.75	4.25	T*	1.00	.75	3.25	T*
1.0 sol.	1.00	1.00	.50	.50	4.00	T*	1.00	1.00	3.00	1
1.0 dry	1.00	1.00	.50	.50	4.00	T*	1.00	1.00	3.00	T*
.75 sol.	.75	.75	.75	.75	3.75	T*	.75	.75	2.25	3
.75 dry	.75	.75	.75	.75	3.75	21	.75	.75	2.25	5
.50 sol.	.50	.50	.50	.50	2.50	30	.50	.50	1.50	45
.50 dry	.50	.50	.50	.50	2.50	38	.50	.50	1.50	75
			First application May 25					First application November 9		
4 sol.	.....	.....	0.75	0.50	5.25	0	.....	.....	4.0	T*
4 dry	.....	.....	.75	.50	5.25	0	.....	.....	4.0	T*
3 sol.	.....	.....	.75	.50	5.25	0	.....	.....	3.0	T*
3 dry	.....	.....	.75	.50	5.25	0	.....	.....	3.0	T*
2 sol.	.....	.....	1.00	1.00	4.00	0	.....	.....	2.0	T*
2 dry	.....	.....	1.00	1.00	4.00	0	.....	.....	2.0	T*
1.5 sol.	.....	.....	1.00	1.00	3.50	0	.....	.....	1.5	2
1.5 dry	.....	.....	1.00	1.00	3.50	0	.....	.....	1.5	2
1.0 sol.	.....	.....	1.00	1.00	3.00	0	.....	.....	1.0	5
1.0 dry	.....	.....	1.00	1.00	3.00	17	.....	.....	1.0	7
.75 sol.	.....	.75	.75	.75	3.00	5				
.75 dry	.....	.75	.75	.75	3.00	23				
.50 sol.	.....	.50	.50	.50	2.00	16				
.50 dry	.....	.50	.50	.50	2.00	42				

* T = Not over three plants per square rod.

Little difference was shown between dry and wet applications. The method of application is largely one of convenience.

AUSTRIAN FIELD CRESS

Austrian field cress (*Roripa austriaca*) is comparatively new in Minnesota, occurring in only a very few locations. Because of its extreme persistence, it is a very undesirable weed plant, and every effort should be made to prevent its further spread.

Fortunately Austrian field cress does not normally produce seed in Minnesota, so it should be possible to eradicate it completely if ordinary care is taken to prevent its spread by vegetative growth. It is one plant that should be wiped out as soon as small infested spots are discovered, and sodium chlorate appears to be an effective means.

In the uniform studies with sodium chlorate, Austrian field cress was eliminated with as little as 2.5 pounds of chemical where an initial application of 2.0 pounds in solution was applied August 12 followed by 0.50 pounds October 10. Chemical treatments are most effective if applied in late summer and early fall (see table 13). However,

Table 13. Comparative Effectiveness in Killing Austrian Field Cress of Uniform Initial Applications of Sodium Chlorate in Pounds Per Square Rod, in Solution or Dry, at Intervals from March to November, and Retreatments, Making the Total Applications Indicated, Olmsted County, 1929

First application, pounds per square rod	Retreatments on			Total application	Per cent full stand June, 1930	Retreatments on			Total application	Per cent full stand June, 1930
	7-15	8-12	10-10			7-15	8-12	10-10		
	Pounds	Pounds	Pounds	Pounds		Pounds	Pounds	Pounds	Pounds	
	First application March 10					First application June 7				
4 sol.	0.50	0.50	.....	5.00	0	0.75	0.75	.....	5.50	0
4 dry	.50	.50	.....	5.00	0	.75	.75	.....	5.50	0
3 sol.	.50	.50	.....	4.00	T*	1.00	.75	0.50	5.25	0
3 dry	.50	.50	.....	4.00	T*	1.00	.75	.50	5.25	2
2 sol.	.50	.50	0.50	3.50	0	1.00	.75	.50	4.25	0
2 dry	.50	.50	.50	3.50	5	1.00	.75	.50	4.25	6
1.5 sol.	.50	.75	1.00	3.75	10	1.50	1.0	1.00	5.00	0
1.5 dry	.50	.75	1.00	3.75	0	1.50	1.0	1.00	5.00	6
1.0 sol.	1.00	1.00	1.00	4.00	0	1.00	1.0	1.00	4.00	0
1.0 dry	1.00	1.00	1.00	4.00	1	1.00	1.0	1.00	4.00	8
.75 sol.	.75	.75	.75	3.00†	0	.75	.75	.75	3.00	4
.75 dry	.75	.75	.75	3.00†	2	.75	.75	.75	3.00	27
.50 sol.	.50	.50	.50	2.00‡	1	.50	.50	.50	2.00	3
.50 dry	.50	.50	.50	2.00‡	8	.50	.50	.50	2.00	48
	First application May 24					First application August 12				
4 sol.	0.50	0.50	.....	5.00	0	.....	.....	0.50	4.50	0
4 dry	.50	.50	.....	5.00	0	.....	.....	.50	4.50	2
3 sol.	.50	.50	0.50	4.50	0	.....	.....	.50	3.50	0
3 dry	.50	.50	.50	4.50	0	.....	.....	.50	3.50	washed out
2 sol.	1.00	.75	.50	4.25	0	.....	.....	.50	2.50	0
2 dry	1.00	.75	.50	4.25	2	.....	.....	.50	2.50	1
1.5 sol.	1.00	.75	.50	3.75	0	.....	.....	1.00	2.50	T*
1.5 dry	1.00	.75	.50	3.75	1	.....	.....	1.00	2.50	4
1.0 sol.	1.00	1.00	1.00	4.00	0	.....	.....	1.00	2.00	4
1.0 dry	1.00	1.00	1.00	4.00	2	.....	.....	1.00	2.00	8
.75 sol.	.75	.75	.75	3.00	T*	.....	.....	.75	1.50	13
.75 dry	.75	.75	.75	3.00	3	.....	.....	.75	1.50	25
.50 sol.	.50	.50	.50	2.00	6	.....	.....	.50	1.00	55
.50 dry	.50	.50	.50	2.00	8	.....	.....	.50	1.00	40
	Single application November 5									
4 sol.	.....	.....	.....	4.00	2					
4 dry	.....	.....	.....	4.00	1					
3 sol.	.....	.....	.....	3.00	2					
3 dry	.....	.....	.....	3.00	3					
2 sol.	.....	.....	.....	2.00	7					
2 dry	.....	.....	.....	2.00	15					

* T = Not over three plants per square rod.
† Includes 0.75 pounds application, May 24.
‡ Includes 0.50 pounds application, May 24.

an initial application of 2.0 pounds March 10, followed by three retreatments of ½ pound each, for a total of 3.5 pounds, gave complete eradication.

A single application of 3 or 4 pounds per square rod November 5 gave nearly complete eradication.

To be reasonably certain of eradication, apply at least 5.0 pounds per square rod. A careful check should be made the following year to spot treat any plants which have persisted. This should secure complete eradication within two seasons.

Control of Annual Weeds

MANY FARMERS are not greatly concerned with the problems arising from annual weeds. Yet the annual weeds in Minnesota as a group do more total damage than the very bad weeds, such as field bindweed. Such weeds as the foxtails (*Setaria* spp.), wild buckwheat (*Polygonum convolvulus*), the pigweeds (*Amaranthus* spp.), wild oats (*Avena fatua*), the ragweeds (*Ambrosia* spp.), mustards (*Brassica* spp.), and others of similar life habit compete with desirable plants and thus reduce crop yields as well as add to the labor of growing the crop. Frequently the seeds of these common weeds are present with the grain to be marketed, and thus they add to the cost of shipping as well as to the expense for their separation in processing. It is difficult to secure exact figures on all of these costs, but it is certain that they are very high.

The best control of common weeds lies in good farming. Use only the cleanest seed. Cleaning the seed grain will do much to reduce the weed population. A good rotation which includes a cultivated crop at regular intervals will destroy many weed plants. Growing grain crops without rotation is certain to result in weedy land which can be cleaned only after many years of careful tillage.

Weedy land will often benefit from deep fall plowing. At the Lamberton station, plowing corn land in preparation for oats resulted in increased yields of 20 to 25 per cent in years when moisture supplies were limited. Common morning glory (*Convolvulus sepium*) is a serious pest in much of the corn belt. A good job of late fall plowing frequently eliminates this weed as a serious factor. Where it is not controlled, it damages the competing crops.

Many of the weeds infesting grain fields can be destroyed and prevented from producing seed by mowing or disking early in the fall while the

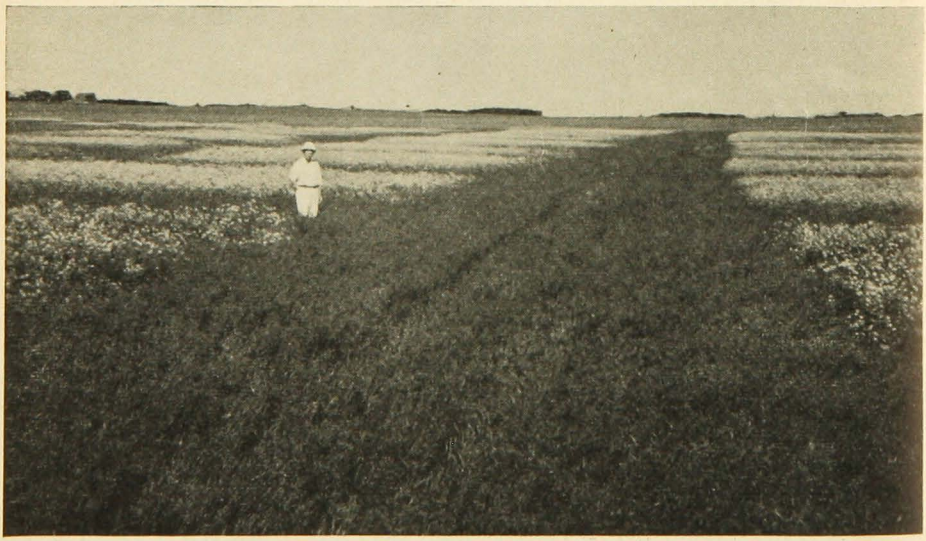

FIG. 10. Dark area, Sinox-treated flax. Light area, flowering mustard in untreated flax.

plants are blooming. This is especially effective with those weeds which develop in small-grain fields after harvest.

Frenchweed (*Thlaspi arvense*), while a biennial, may be considered here because it frequently grows as a winter annual and is controlled in much the same manner as annual weeds. Disking of the stubble early in the fall before plowing will promote the germination and growth of the seeds. Subsequent cultivations will destroy many seedlings.

The flax grower is troubled with many weeds, as flax, because of its open growth, is a poor competitor. Recent experiments with a proprietary preparation reported to contain a sodium salt of dinitrocresol as its principal active ingredient (a commercial form is known as Sinox) have indicated that it is selective in its action; that is, the chemical will kill certain weedy plants and not injure the flax. It was applied at the rate of one gallon of sodium salt of dinitrocresol to 80-100 gallons of water, per acre. An activator was added according to manufacturer's instructions. Sprayed when weeds were in a rosette stage, this chemical was effective in eliminating the mustards. Also, it destroyed wild buckwheat plants even after they were quite large, but it was rather ineffective in the control of grass weeds such as the foxtails. It appears from preliminary experiments that this chemical is especially suitable for destroying many annual weeds which infest fields of flax—primarily mustard, wild radish, wild buckwheat, and ragweeds.

This sodium salt of dinitrocresol is likely to destroy legume seedlings. It is not recommended on areas where legumes have been planted with the flax crop. Sweet clover appears to be most subject to injury, with alfalfa somewhat more resistant.

Lawn Weeds

PROBABLY no other group is more weed conscious than home owners. The person who tries to maintain a good lawn is so beset by numerous persistent weed plants that frequently he is tempted to give up in disgust and let nature take her course.

To control lawn weeds, one must start with good seed. Lawn seed, because of its size, is likely to contain undesirable weed seeds. It is best to buy only from a reliable seedsman, making certain that there are no bad weed seeds present.

A well-prepared, fertilized, firm seedbed will make possible rapid growth of the grasses so that they may become established and thus compete successfully with the weeds. Lawns may be started in the spring or fall. Frequently it is advisable to seed a fast-growing crop such as perennial rye grass with the basic lawn mixture to provide shade for the slower-growing plants.

Kentucky bluegrass, the most common lawn grass, under average conditions, will not grow during the heat of the summer unless there is an abundance of moisture. It becomes dormant at this time and resumes growth with the coming of cool weather in the fall. It is during this dormant period that one of the worst weeds, small crabgrass (*Digitaria humifusa*), gets a foothold in the lawn. It grows so rapidly and produces so much seed that it is extremely difficult to control. Once bluegrass is dormant, it remains dormant during the dry hot weather of the summer and crabgrass grows more vigorously.

Crabgrass may be destroyed by several methods. A sure but laborious process is to dig out the plants as they appear and not to permit seed formation. After two or three years, if no crabgrass seed is introduced, the lawn should be fairly well cleaned. The use of a rake to raise up the prostrate stems will make possible closer mowing. The lawnmower may be equipped with a rakelike device which raises up the stems so that they are cut off. All clippings should be removed and burned to prevent reseeding.

Certain chemicals have proved of value in destroying crabgrass. Some proprietary compounds are effective in destroying the annual crabgrass while permitting the perennial bluegrass to recover. Very good results have been secured at University Farm from an application of water-white kerosene, (Color Saybolt 23) to which a small amount of soap dissolved in soft water has been added, applied as a spray at the rate of ½ gallon to 100 square feet. This mixture has killed the crabgrass without destroying the bluegrass or the white clover. Applications should be made before seed is formed, preferably when the crabgrass is in the two-leaf stage and before flower stalks are formed. Apply in late afternoon of a day with temperature below 85°-90° F. Water heavily the following morning.

The dandelion (*Taraxacum* sp.) is another serious weed of lawns. It is a perennial so it persists once it is established. A few plants permitted to flower produce an abundance of seed and the infestation gets worse and worse.

Effective dandelion control measures vary widely. Through early spring reseeding and fertilizing, the grasses may be encouraged so as to give real competition to the dandelion as well as other weeds. Cutting the root at least 4 inches below the soil surface will destroy the plant. If this is done each year, one can eliminate the weeds.

Application of ½ gallon of water-white kerosene to each 100 square feet in the fall of the year has been an effective method of control in many sections. A few drops of kerosene may be applied to each individual plant where the weeds are scattered. A few drops of sodium chlorate solution applied on individual plants has given good results in some cases. Certain manufactured spray materials are available to the home owner. Some of these are of little or no value and should be used on a trial basis only. In trials at the Minnesota Agricultural Experiment Station, the herbicides tested have not proved superior to kerosene.

Many other weeds may compete with lawn grasses and legumes. The mouse ear chickweed *(Cerastium vulgatum)* is a persistent perennial. It is recognized by the small mouse ear shaped leaves and the tiny white flowers. Kerosene may be applied as recommended for crabgrass. Treatment is made at any time of the year prior to the formation of flowers and seeds.

In the control of lawn weeds a good defense is to attack first. Proper sowing of pure seed, regular application of fertilizer, digging out occasional weeds, regular and thorough watering (not sprinkling), and the avoidance of too close mowing will go far toward the control of weeds. Very often the lawn is weedy because the mower cuts so close that the grass never has a chance to get established. This may be remedied by raising the cutting bar to permit higher cutting. However, close cutting is desirable for bent grasses.

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